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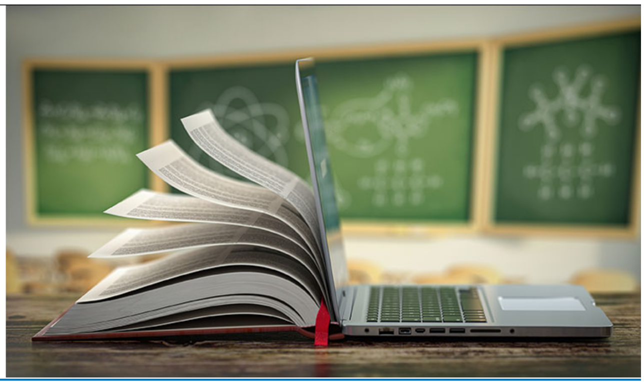

A compact 3-dB coupler with stubs

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Abstract. High wave resistance line and no-load stubs were used as a tool for reducing the area of directional coupler on microwave substrate. Replacement of all λ/4 sections (segments) that are part of the coupler with the described artificial transmission lines allowed to reduce the area of the device by 76,8% (with frequency 1.9 GHz). Mathematical calculation and analysis of devices was made using Cadence AWR DE. The manufactured layout has comparable characteristics with the characteristics obtained for the model in AWR program. Negative aspects of miniaturization are narrowing of the line and increasing losses at the coupler.

1. Introduction

Intense development of telecommunication systems requires integration of miniature and reliable microwave devices in its architecture, which include devices such as filters, phase shifters, directional couplers and others. To get compact devices it is necessary to find approaches, allowing not only reduce their size but also to maintain their reliability. Traditionally, λ/4 sections are used to create directional couplers, calculated for their wave resistance and operating frequency. As known, length of wave and frequency has a direct relationship, as frequency increases, length of wave decreases, and conversely, when the frequency is lowered, it increases. For this reason, miniaturization of microwave devices is most relevant at low frequencies, where λ/4 sections have significant length. The simplest but less efficient way to miniaturize a directional coupler is to bend lines into the inner space of coupler while preserving their lengths. It is also possible to reduce size using substrate with high values of permittivity. However, it is not always possible in practice due to the use of specific material for making the device. Today in international database IEEE you can find a large number of works related to the miniaturization of microwave devices, for example, in [1] – [19] describes constructions of miniature couplers, each construction has its own advantages and disadvantages. Our work presents the results of research on compact coupler, the area of which was reduced by using a set of elements (high-resistance lines and idle stubs). One of the main advantages using this approach is the speed and ease of obtaining the topology of compact coupler. Construction of the coupler model and its analysis will be carried out in the AWR Cadence program.

2. The main part

A directional coupler is a device which divides input power between two outputs. The values of the transfer coefficients are determined from the ratios of sections' wave resistances. So for equal power division between outputs of the coupler, sections must have wave resistances equal to 35 and 50 Ohms, respectively. Using built-in tool TXLine in the AWR program, the standard implementation of such a coupler was calculated. Layout of the coupler on FR4 substrate and operating frequency of 1.9 GHz is presented on figure 1. In this implementation coupler occupies 640.75 mm^2 on the microwave substrate.

Graphs, obtained during the mathematical calculation are presented in Fig. 2 and Fig. 3. The device's bandwidth will be estimated by the -15 dB decoupling level.

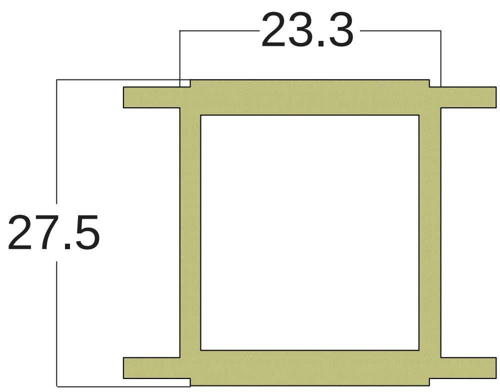

Figure 1. Layout of the directional coupler.

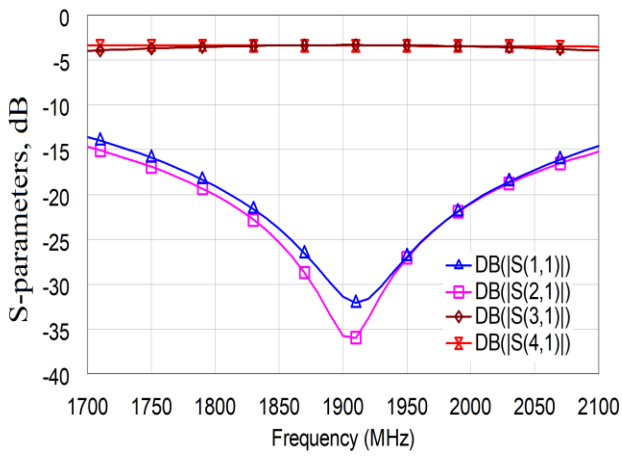

Figure 2. Graph of S-parameters from the frequency of the coupler.

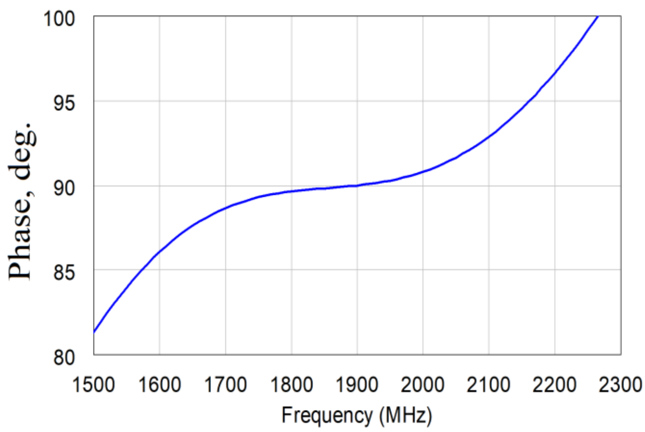

Figure 3. Graph of the phase difference between the outputs of the coupler.

At a central frequency of 1.9 GHz, coupler has a bandwidth of 400 MHz (21%), the transfer coefficients have values equal to -3.5 and 3.5 dB. Transfer coefficients balance is observed in the frequency band 1750-2050 MHz. The phase difference between the output signals is 90 degrees. Next iteration was the synthesis of structures, consisting of high-resistance lines acting as a inductive elements and idle stubs, which at length less than λ/4 plays the role of capacitive elements. These structures are calculated in such a way as to provide similar characteristics to normal lines – this is the minimum transfer coefficient in the band and phase range 90 degrees at the operating frequency of the device. It is also worth noting that the stubs are located in the inner space of the coupler to ensure the best performance on device miniaturization. After the structures are calculated, they are installed instead of the λ/4 sections that are part of the traditional coupler. That replacement made it possible to reduce size of the device by 76.8% (148.6 mm^2). Layout of reduced size coupler is shown on figure 4. Characteristics of that coupler are shown on figure 5 and figure 6.

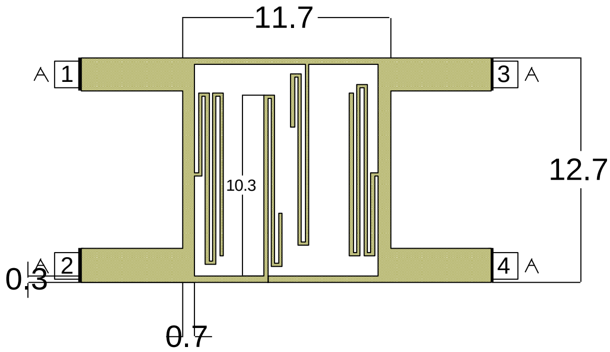

Figure 4. Layout of the compact coupler

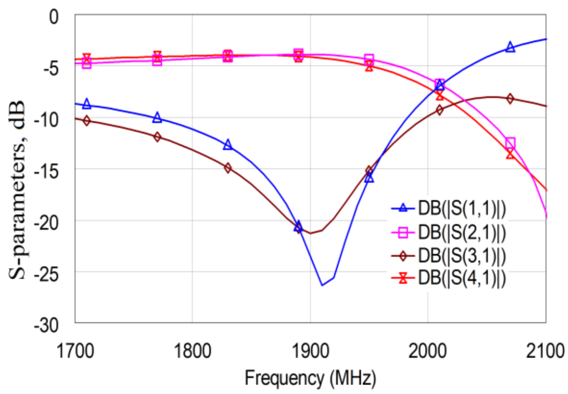

Figure 5. Graph of S-parameters from the frequency of the compact coupler

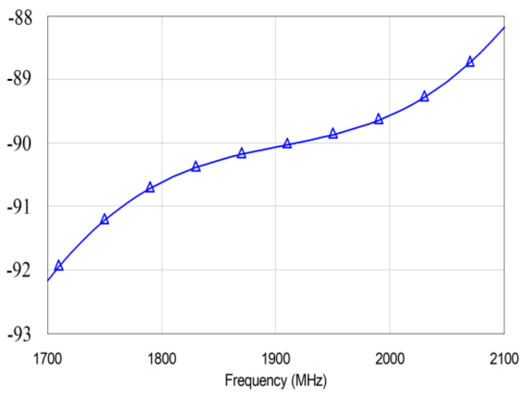

Figure 6. The phase difference between the outputs of the compact coupler.

At a central frequency of 1.9 GHz, compact coupler has a bandwidth of 120 MHz (6.3%), transfer coefficients have values equal to -3.8 and 4 dB. The phase difference between the output signals is 90.2 degrees. It can be seen that size decrease has led to a significant narrowing of the working band. This is due to the fact that the characteristics of the structures used are similar to characteristics of λ/4 sections in a narrow frequency band (the phase-frequency characteristic of the structures has a greater slope). To verify the correctness of calculations, a prototype of the device was made (figure 7). Vector network analyzer Rode&Shwarz ZVA24 allowed obtaining experimental characteristics of the prototype (figure 8, figure 9).

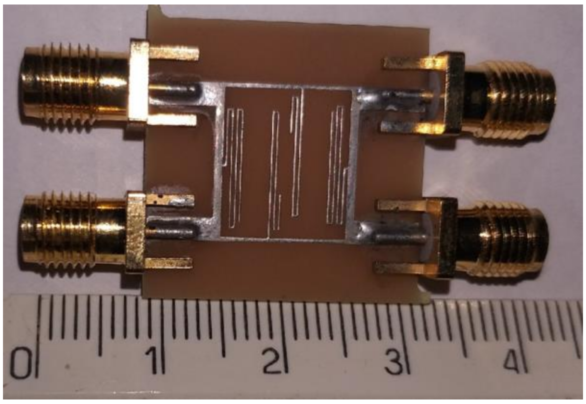

Figure 7. The model of the compact coupler.

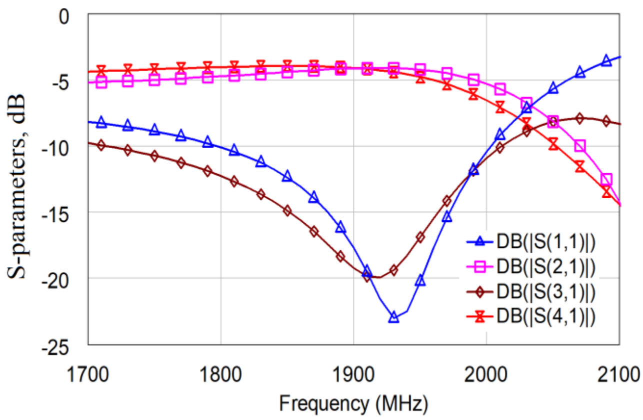

Figure 8. Dependence of S-parameters on frequency obtained as a result of a field experiment.

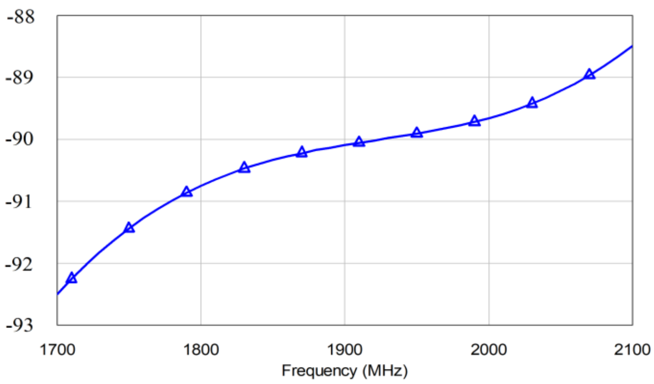

Figure 9. The phase difference between the transfer coefficients at the output of the manufactured coupler.

At a central frequency of 1.92 GHz the prototype has a bandwidth of 114 MHz (5.9%) transfer coefficients have values equal to -3.95 and 4.1 dB. The phase difference between the output signals is 90.5 degrees. For comparison, the main indicators of a conventional and compact coupler are summarized in table 1.

Table 1. Comparison of the numerical and measured results

Parameters	**Standard**	**Compact**
Bandwidth, MHz	400	114
Area, mm^2	640.75	148.6
Relative Area, %	100	23.2
Central Frequency, MHz	1900	1920
The Phase Outputs	90	90.2

3. Conclusion
The obtained experimental results show the possibility of using structures consisting of lines with high wave resistance and idle stubs, as a tool for size miniaturization of directional couplers. This work has presented a prototype of a compact coupler with a center frequency of 1.9 GHz, its area has been reduced by 76.8% compared to a conventional device. However, there have been changes in the characteristics of the device that are most associated with reduced bandwidth.

ACKNOWLEDGMENTS
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